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28 April 1980

USSR Report

SPACE

(FOUO 4/80)

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CONTENTS

MANNED MISSION HIGHLIGHTS

COSMONAUT KLIMUK DESCRIBES 'SOYUZ-T' MISSION PLANS

Paris AIR & COSMOS in French No 800, 16 Feb 80 pp 50-51

[Article by Pierre Langereux: "New Revelations on the 'Soyuz-T' Vehicle"]

[Text] On 1 February 1980 in Paris, where he was attending the Young Communist Congress, Soviet Cosmonaut Petr Klimuk revealed to us that the USSR will continue to utilize simultaneously all three types of space transport vehicles at its disposal: the "Progress" automatic freight transport, the conventional "Soyuz" manned vehicle and the new "mixte" "Soyuz-T" vehicle.

Petr Klimuk also told us two important things about the new "Soyuz-T":

--first of all, that it is a "mixte" vehicle, designed to transport either cargo or a crew, of two cosmonauts (and not three), as has become the rule on Soviet transport ships.

--secondly, that the new "Soyuz-T" would not in the immediate future totally replace the conventional "Soyuz" even though it has been further refined for manned flights. Petr Klimuk said that "Soyuz-T" could be used for the program of Soviet spaceflights (for Soviet cosmonauts only) whereas the program of international flights (with crews consisting of cosmonauts from the USSR and other communist countries) would continue to use the conventional "Soyuz."

The reason for maintaining this duality of the "Soyuz" and "Soyuz-T" vehicles, at least for the short term, is obvious: it involves the rather long delay in training pilots for the new vehicle. At least 1 year of training on the ground flight simulator will be required for the crew to fly "Soyuz-T." Petr Klimuk, himself a veteran pilot-cosmonaut, told us that it took him about one and a half years to be able to pilot this new "Soyuz-T."

Under these conditions it is understandable that "Soyuz-T" will not immediately replace the conventional "Soyuz" even though it constitutes a significant advance over the old vehicle, in which the role of "pilot" was rather limited. According to the Americans--who had the opportunity to know in detail the [redacted] [redacted]

old "Soyuz" during preparations for the joint Apollo-Soyuz flight in July 1975, the capabilities of conventional "Soyuz" are inferior to those of the American Mercury series of 18 years ago.

Easier to Pilot

The "Soyuz-T" vehicle has some very clear improvements over the conventional "Soyuz," even though the external appearance and the total mass have been modified relatively little. However, "Soyuz-T" seems to be a vehicle that can truly be "piloted" by the crew and, therefore, is closer to the more recent American space transport ships.

The principal improvement, according to Petr Klimuk, is that the "Soyuz-T" is easier to fly thanks, in particular, to the addition of a digital computer (as on the U.S. vehicles) to calculate the operations for rendezvous between the transport vehicle and the "Salyut" orbital station, which permits fuel conservation and allows the crew to concentrate on piloting. All the information relevant to the flight mode and to rendezvous operations are displayed on a single screen on the control panel, which will greatly facilitate the crew's work. With the conventional "Soyuz" all of this information was sent to the Flight Control Center, which, after computer processing there, gave orders for piloting and maneuvering. This resulted in a certain number of failures to dock "Soyuz" with the "Salyut" stations. However, with "Soyuz-T" all flight data will be sent also to the control center by a data transmission link (telemetry), which will reinforce flight safety by preserving past procedures.

Klimuk explained to us that the maneuverability of "Soyuz-T" (the total increase in velocity provided by the thrusters) has also been improved, specifically by "unifying" the propulsion systems for orbital maneuvers (main engine) and for attitude control (secondary engines). From now on, the two propulsion systems will use the same fuels and the same tanks (as on U.S. spacecraft), allowing the stored fuels--unsymmetrical dimethylhydrazine (UDMH) and nitrogen oxide (N_2O_4)--to combine. On "Soyuz-T" the attitude control uses, therefore, hot gas jet engines (instead of cold gas jet engines). In addition, the new "Soyuz-T" engines are fed by pressurized tanks instead of the conventional "Soyuz" turbopump main engines, thereby increasing the craft's reliability. The "Soyuz-T" unified propulsion system is, thus, similar to the propulsion system of the new second generation "Salyut" ("Salyut-6"), which is also unified; this ensures a complete communality between the transport ship and the station, which, in turn, results in greater mission flexibility.

The autonomous flight mode for "Soyuz-T" has also been expanded with the possibility of equipping the new vehicle with solar panels. Recently Konstantin Feoktistov, cosmonaut and chief "Salyut-6" designer, had indicated that "Soyuz-T" currently carries the solar panels (smaller but more efficient than those initially installed on "Soyuz" ships for autonomous flights). However, Petr Klimuk explained that solar panels "can" be installed on

"Soyuz-T", but that this is not foreseen at present. Klimuk indicated that "Soyuz-T" will use power from the "Salyut" orbital station (which has three large solar panels), just as the other Soviet transport ships. And it is only for autonomous missions (such as those already flown by "Soyuz" for remote sensing) that "Soyuz-T" will make use of its own power source.

This thinking then is in line with the fact that the Soviets have improved the piloting and maneuvering capabilities of "Soyuz-T." That is to say, if the improvements made to the guidance and propulsion systems permit the new vehicle to dock more reliably and rapidly with the orbital station, it would not seem necessary to equip "Soyuz-T" with a supplemental energy source (solar panels) in addition to rechargeable batteries. Moreover, it would be at the price of a weight increase. Within the same volume, "Soyuz-T" designers obviously had to redistribute mass in order to increase fuel reserves and instrumentation over that of "Soyuz-T," while reinforcing the overall structure. That could not have been easy even if "Soyuz-T" makes use of lightweight materials and microelectronics.

A Several-Month Mission for 'Soyuz-T', 'Salyut-6'

The first "Soyuz-T," which was launched on 16 December 1979 (at 1530 Moscow time), had already displayed its capability in the automatic flight mode when it was docked to the "Salyut-6" orbital station (at the forward docking port) on 19 December (1709 Moscow time)--3 days after the launch! During this time "Soyuz-T" performed various orbital maneuvers, in particular, an imaginary rendezvous at a predetermined point in space, before docking with "Salyut-6;" this docking was conducted completely automatically because there was no crew on board for this first test flight.

It remains, therefore, to demonstrate the "Soyuz-T" manned rendezvous capability. It seems, however, that this operation will not come to pass in the immediate future if one can believe the recent Soviet statements--made in early January--that announced that the first "Soyuz-T" will remain docked with "Salyut-6" for several months!

This gives further indications of Soviet intentions, in light of the fact that the "Salyut-6" station is effectively in good condition after 2 years in orbit (it was launched 29 September 1977). Petr Klimuk also confirmed that the "Salyut-6" station could be used again, explaining that a new crew would soon be launched. But Klimuk also said that at the present time there is no crew awaiting takeoff at Baykonur, which indicates that there will not be a launch within the next 2 weeks (the crew arrives at the launch site 15 days before takeoff).

In addition, it is logical to leave "Soyuz-T" docked to "Salyut-6" for a rather long time in order to verify the new vehicle's orbital lifetime. The orbital lifetime of transport ships (limited to 90 days for the conventional "Soyuz") should tend to follow the evolution of missions on board the station which now last 6 months! This record, Klimuk reminds us, was achieved progressively: 18 days, then 24, 30, 63, 96, 140 and finally 175 days.

By increasing the orbital lifetime of the new transport ships, the Soviets could thus reduce the number of launches. However, the short-duration "visiting" expeditions would not be discontinued because it is believed that these encounters bring about a psychological and emotional break in routine that is beneficial to crews in orbit for several months.

Klimuk revealed that a specialized psychological support program has been initiated by the Soviets. This program begins with the selection of the two crew members, who must be "complementary" in their character and behavior. During the mission this program serves to create the impression of human contact for the crew through short visits by other cosmonauts, TV liaison with their friends and families (filmed under conditions desired by the crew), recordings of earth noises (rain, etc) played as the cosmonauts sleep, and "special films" making it possible for the crew to tolerate the absence of women on board.

Cosmonauts can thus endure without apparent damage long-duration flights. Petr Klimuk revealed that the crew of the record 6-month mission, despite its isolation (the crew did not receive one visiting expedition), returned in "rather good condition," more or less better than expected.

The major concern stemmed from the fact that every 140 days blood is completely renewed in the human body; but this resulted in no unfortunate consequences, according to Klimuk. On the other hand, upon their return to earth, the cosmonauts experienced vestibular problems, notably a heaviness while walking coupled with the desire to lie down, etc.

The crew, therefore, underwent a program of gradual readaptation to the earth's gravity, which made it possible for the cosmonauts to recover completely in 1 1/2 months. The crew of the record-breaking mission could have walked in just 10 days after returning, but Soviet doctors imposed a progressive readaptation.

This readaptation is also facilitated by continued monitoring and rigorous exercise on board the station throughout the flight. Klimuk explained that it takes about 3 days for the crew to adapt to weightlessness and to overcome the nausea caused by rapid shifting in the station. In spite of this, the sensation of weightlessness is very pleasant for cosmonauts. They work 10-12 hours per day on board "Salyut" stations: 4 meals a day, 8 hours sleep, 1-1 1/2 hours leisure time, which the cosmonauts generally use for scientific research work (either within the flight program or personal). The crew is given one day off each week.

Throughout the several months spent on board a station, a program of prophylaxis is followed in order to avoid muscular atrophy and weakening and cardiovascular problems. Since 1975 Petr Klimuk, together with Cosmonaut Vitaliy Sevast'yanov, have studied the prophylactic measures for use on board space vehicles during long-duration flights, work which won them a state prize.

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[redacted]

The crews of Soviet orbital stations prepare for a long time before they return to earth using, in particular, specially-designed equipment: daily exercise (40 min) with the bicycle ergometer and treadmill (for the leg muscles) and with expanders (for the arms and back) and electric stimulators (muscle reflexes). The cosmonauts are also required to wear throughout the day (except while sleeping and exercising) a special suit which maintains stress on the muscles and skeleton. Finally, 10 days before landing, they wear for several minutes each day the "Chibis" pants, which restore normal blood circulation in the lower part of the body.

The USSR will continue to increase gradually the length of spaceflights, according to Petr Klimuk, who estimates that it will be possible to conduct 1-year missions, but who could not say precisely when this stage will be attained.

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SPACE SCIENCES

THERMAL SOUNDING OF THE ATMOSPHERE FROM 'SALYUT-6'

Moscow DOKLADY AKADEMII NAUK SSSR in Russian Vol 248 No 4, 1979 manuscript received 19 Jul 79 pp 828-831

[Article by G.M. Grechko, A.S. Gurvich, Yu.V. Romanenko, S.A. Savchenko and S.V. Sokolovskiy, Institute of Physics of the Atmosphere of the USSR Academy of Sciences, Moscow: "Vertical Temperature Distribution in the Atmosphere According to "Salyut-6" Refraction Measurements"]

[Text] When the sun is observed from high altitudes, when its rays pass through the atmosphere rather low above the horizon, its image is compressed vertically. This is indicated by photographs of the sun made by American astronauts [4] and by Soviet cosmonauts [2]. Compression of the sun's image is caused by refraction of the optical beams in the earth's atmosphere. Let us denote by φ the zenith angle of the beam at the observation point, located at altitude h above the earth's surface (see Figure 1), and by ψ the angle between the vertical at the observation point and the initial direction of the beam (R is the earth's radius). Since the average refraction angle ε decreases rapidly with an increase of altitude z_0 of the perigee of the beam, this leads to the fact that the angle between the two beams at the observation point is less than the initial angle between them by a value equal to the difference of the refraction angles for these beams. As a result the sun's image acquires the shape of an asymmetrical oval compressed more on the bottom than on top. The extent of compression of the solar disc was calculated for different models of the atmosphere and was compared to photographs in [2].

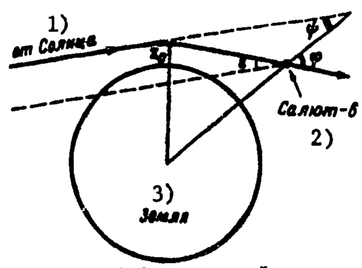


Рис. 1. Геометрия лучей

Figure 1. Configuration of Beams

Key:

1. From sun 2. "Salyut-6" 3. Earth

G.N. Grechko and Yu. V. Romanenko noted while working on the "Salyut-6" orbital station that deformations in the form of steps are frequently visible on the solar limb, i.e., a finer structure of the image is observed than simple compression caused by a smooth decrease of the refraction angle with altitude. The sun was photographed at sunrise and at sunset using a lens with focal distance of 0.9 meter for quantitative analysis of these deformations. Three of the photographs on which deformation of the sun's limb is well visible in the form of steps are presented in Figure 2.

The described deformations of the solar image can be explained by taking into account the perturbations of the refraction angles caused by variations of the altitude temperature profile which are typical for temperature inversions.

A spherically symmetrical model of the atmosphere was used in the calculations. The refractive index n can be represented in the form of $n(z) = 1 + \mu(z)$; the value of μ in the optical band is proportional to atmospheric density. All the beams arriving from the sun at the observation point were assumed as lying in the same plane and thus only the vertical deformation of the image was considered. Horizontal deformation for the observer's altitude of h = 350 km (the orbital altitude of "Salyut-6") was 2-3 orders less and can be disregarded.

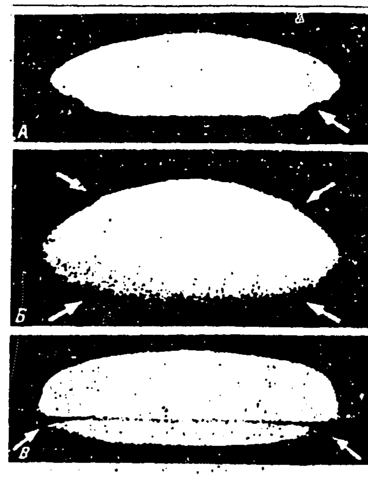
A simple scheme for constructing the image of the solar limb for a given profile of the refractive index was used to compare the results of calculations to experimental data. In the absence of an atmosphere, the curve describing the visible shape of the solar disc in coordinates x is given by the equation of a circle $x^2 + (\psi - \psi_0)^2 = d^2$ (x is the angular coordinate parallel to the horizon, ψ_0 is the direction toward the center of the sun and d is the angular diameter of the sun). Being given profile n(z), one can calculate the function $\psi(\varphi)$. The curve which describes the sun's image visible through the atmosphere in coordinates φ, x will then be given by the equation $x^2 + [\psi(\varphi) - \psi_0]^2 = d^2$. It is practically convenient when constructing the image to assume that variable z_0 is independent. From Snellius's law

$$(R + z_0)n(z_0) = (R + h)\sin\varphi \tag{1}$$

it is easy to determine φ for a beam with perigee of z_0. Then calculating the angle of refraction

$$\epsilon = -2(R + z_0)n(z_0) \int_{z_0}^{\infty} \frac{(dn/dz)dz}{n(z)[(R+z)^2 n^2(z) - (R+z_0)^2 n^2(z_0)]^{1/2}} \tag{2}$$

we find the value $\psi = \varphi - \epsilon$ for this beam. The corresponding point on the image will have an abscissa of $x = [d^2 - (\psi - \psi_0)^2]^{1/2}$ and ordinate of φ.



(Photo not available)

Figure 2. Solar Images Visible Through the Earth's Atmosphere Obtained From the "Salyut-6" Orbital Station. The arrows indicate the "steps"

The approximate expression found in [3] in the first approximation of expansions by the small parameter $R(d\mu/dz)$ was used instead of (2) for the angle of refraction

$$\epsilon = -[2(R + z_0)]^{1/2} \int_{z_0}^{\infty} (d\mu/dz)(z - z_0)^{-1/2} dz. \tag{3}$$

Images were plotted on a Hewlett-Packard 9820A computer having a graph plotter by the scheme described above for constructing an image for different models of the density profile, which were then compared to available photographs.

It turned out that by using the exponential density profile

$$\bar{\mu}(z) = \alpha \exp(-z/H) \tag{4}$$

the total (smooth) deformation of the sun's image is easily modelled. The perturbed density profile was used to model deformations of the image with finer structure

$$\mu(z) = \bar{\mu}(z)[1 + \delta(z)].$$

Deformations of the image in the form of steps are easily modelled by concentrated perturbations of the type

$$\delta(z) = \begin{cases} 0 \text{ при } z < z_x - \Delta/2, \\ 0 \text{ при } z > z_x + \Delta/2, \\ a[16(z-z_x)^4/\Delta^4 - 8(z-z_x)^2/\Delta^2 + 1], \end{cases} \tag{5}$$

where z_x is the altitude of the cente. of perturbation, Δ is its thickness and a is amplitude.

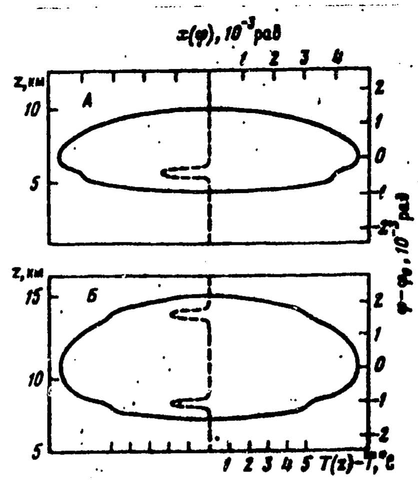


Figure 3. Calculated Images of the Solar Limb: φ_0 is the direction toward the center of the sun. The dashed lines show temperature disturbances (9). For A: a = −2.5°C, Δ = 1.2 km and z_x = 5.5 km; for B: a = −2°C, Δ = 1.2 km, the bottom step z_x = 8 km and the top step z_x = 14 km.

The following expression is found for the angle of refraction:

$$\epsilon = \bar{\epsilon} + \delta\epsilon, \tag{6}$$

$$\bar{\epsilon} = \alpha[2\pi(R+z_0)/H]^{1/2}\exp(-z_0/H), \tag{7}$$

$$\delta\epsilon = -\alpha[2(R+z_0)]^{1/2}\exp(-z_x/H)\int_{z_0}^{\infty}\frac{d\delta(z)}{dz}(z-z_0)^{-1/2}dz. \tag{8}$$

As is easily shown, the temperature disturbance corresponds to relative density perturbation of type (5) in the first approximation for small parameters a and Δ/H

$$\delta T \simeq -\bar{T}(z_x)\delta(z). \tag{9}$$

The dependence of temperature on altitude of type (9) can be realized in the presence of a temperature inversion in the atmosphere and characterizes the layer in which a break of the temperature profile occurs [4].

The calculated images of the solar disc, constructed by using formulas (5-8) are presented in Figure 3. The values of parameters $\alpha = 3\cdot10^{-4}$ and H = 7.5 km were taken for an undisturbed profile μ (z). The values of z_x, a and Δ were selected such that the position of the step, its amplitude and width corresponded to Figure 2, a and b.

Figure 2, b is very interesting. The solar image on it is divided into two parts by a dark band. It was impossible to construct a satisfactory calculated image for this photograph within the framework of the proposed model of the temperature profile. However, by assuming that the origin of the dark band on the image is caused by refraction, one can approximately estimate the temperature disturbance required for this. The presence of the dark band visible at angle φ may mean that beams coming from points located below the sun are arriving at a given angle. Perturbation of the refraction angle $\delta\epsilon$, at least equal to the angular thickness $\delta\varphi$ of the smaller (lower) part of the image, i.e., $\delta\epsilon = \delta\varphi$, is required for this. Using the model of perturbation (5), expression (8) for $\delta\epsilon$ and assuming that $z_0 = z_x$, we find

$$\alpha[2(R+z_x)]^{1/2}\exp(-z_x/H)[3a/(2\Delta)^{1/2}] = \delta\varphi. \tag{10}$$

The values of z_x and Δ can be found approximately from measuring the total compression of the image and the angular thickness of its strongly deformed part (in the vicinity of the band). Numerical estimates for Figure 2, b yield $z_x \simeq 6$ km, $\Delta \simeq 1$ km and $\delta\varphi$ - $7.5 \cdot 10^{-4}$. Then on the basis of (10), we find a $\simeq$ 0.025, i.e., for the dark bank on the image to occur with the parameters indicated above, a temperature disturbance of 5-10°C concentrated in the range of altitudes of 1 km is sufficient.

The experiment and its processing showed that small scale inhomogeneities of the temperature profile may contribute to sufficient refraction for the occurrence of appreciable deformations of the solar image. This indicates the possibility of using refractometric methods to determine the fine structure of the temperature profile in the atmosphere. We note that existing methods of thermal sounding of the atmosphere [5] do not have the resolution sufficient to determine the temperature profile inhomogeneities with the parameters indicated above.

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OPTICAL STUDIES IN SPACE

Leningrad OPTICHESKIYE ISSLEDOVANIYA V KOSMOSE in Russian 1979 signed to press 17 Aug 79 pp 3-9, 235-236, 254-255

[Introduction, conclusion and table of contents from book by Aleksandr Ivanovich Lazarev, Andriyan Grigor'yevich Nikolayev and Yevgeniy Vasil'-yevich Khrunov, Gidrometeoizdat, 11,500 copies, 255 pages.]

[Text] Introduction

With the beginning of the space era there have been extensive opportunities for the penetration of man, measuring instruments and scientific space laboratories into previously inaccessible regions of near-earth and interplanetary space. Large-scale investigations of physical processes and phenomena taking place on earth, in near-earth space, on the moon and other bodies of the solar system have proved possible from space orbits. The introduction of extra-atmospheric astronomy has made accessible for research many regions of the infrared, ultraviolet, x-ray and gamma radiation absorbed by the earth's atmosphere.

Optical research from space is one of the most important methods of studying the earth's natural resources, the physical properties of the atmosphere, and interplanetary and outer space. Investigations of atmospheric optical phenomena occupy an important place in the study of physical processes taking place in the atmosphere of the earth and the planets, as well as in the gas-and-dust tails of comets. A number of atmospheric optical phenomena are most distinctly evidenced in observations from space in the direction of the horizon. In this connection, optical studies at the horizon of the earth and planets have taken on great importance.

The first observations from space were made by Yuriy Alekseyevich Gagarin, who observed the exceptional abundance of colors of the earth's horizon during the daytime and at twilight. With each succeeding manned flight cosmonauts observed and recorded different optical phenomena and physical processes in the atmosphere and on the earth's surface. In this book an attempt is made to systematize, analyze and generalize the results of optical observations and studies from Soviet manned spaceships. In some instances, results obtained by American astronauts are also utilized. In the first chapter, which is devoted to the history of optical research from Soviet spaceships, it is demonstrated how new experimental facts have gradually been accumulated and how the scope of investigations has been expanded. G.S. Titov was apparently the first to observe the glowing particles later described by American Astronaut J. Glenn (the Glenn effect). A.G. Nikolayev and P.R. Popovich, after their flights in the spaceships "Vostok-3" and "Vostok-4," related in detail how the earth looks from space.

Observations of polar auroras and of the nocturnal, twilight and daytime horizon of the earth were made by the crew of the spaceship "Voskhod." The observations of A.A. Leonov from the spaceship "Voskhod-2" are interesting. From the results of these observations A.A. Leonov drew the color pictures "Morning in Space," "Earth's Azure Belt," etc., which are of not only artistic, but also scientific value. This has been confirmed by analysis of the atmospheric optical phenomena engraved on A.A. Leonov's pictures.

An extensive program of visual observations and optical instrument studies of the earth's water area, dry land, cloud cover and atmosphere and of outer space has been carried out from the "Soyuz" spaceships. G.T. Beregovoy ("Soyuz-3") and A.G. Nikolayev and V.I. Sevast'yanov ("Soyuz-9") observed for the first time the characteristic pattern of the spatial distribution of the emissive radiation of the earth's upper atmosphere in the twilight zone. These observations served as the basis for a discovery by Soviet scientists and cosmonauts of the "phenomenon of the vertical-radiation structure (horizontal inhomogeneity) of the emissive radiation of the earth's upper atmosphere." From the "Soyuz-5" spaceship spectrophotometric scanning of the daytime and twilight horizon was conducted. V.A. Shatalov observed from the "Soyuz-4" spaceship the contrail of the booster which took "Soyuz-5" into orbit. A number of interesting results of optical observations of cyclones, typhoons, forest fires and dust storms were obtained by G.S. Shonin, V.N. Kubasov, A.V. Filipchenko, V.V. Gorbatko, V.N. Volkov, V.A. Shatalov and A.S. Yeliseyev in the group flight of "Soyuz-6," "Soyuz-7" and "Soyuz-8." From "Soyuz-7" V.N. Volkov continued the spectrophotometric scanning of the earth's atmosphere and surface. A.G. Nikolayev and V.I. Sevast'yanov in their flight in "Soyuz-9" observed for the first time the projection of the radiation of part of the twilight atmosphere over the noctilucent layer (the "moustache" effect).

Certain features in the spatial distribution of the radiation of the earth's nocturnal atmosphere in the equatorial zone were observed by V.G. Lazarev and O.G. Makarov from "Soyuz-12". More than 10,000 spectra of hot and cold stars in the ultraviolet region of the spectrum were obtained by P.I. Klimuk and V.V. Lebedev by means of the "Orion-2" equipment installed on board "Soyuz-13." Cosmonauts L.S. Demin and G.V. Sarafanov observed the discrete structure of diffuse polar auroras from "Soyuz-15."

A big step in the conquest and study of space involves the introduction of the "Salyut" multi-purpose scientific stations.

Installed on board a "Salyut" orbital station was an "Orion" telescope, which was designed to obtain the ultraviolet spectra of large stars. P.R. Popovich and Yu.P. Artyukhin photographed from the "Salyut-3" orbital station a considerable portion of the territory of the Soviet Union. These photographs were used for solving many scientific and national economic problems. Installed on board the "Salyut-4" orbital station were x-ray, solar and infrared telescopes and a complex of optical apparatus for photographing and spectrophotometric scanning of the earth's atmosphere and surface. One of the unexpected results obtained by the first crew of the "Salyut-4" orbital station, which consisted of A.A. Gubarev and G.M. Grechko, was the considerable Doppler shift in emission lines of atoms in regions of plages. From the value of this shift it was established that the rate of motion of matter in individual regions of the sun can reach 100 km/s. Members of the second expedition of the "Salyut-4" orbital station, in addition to optical instrument studies, paid great attention to studying noctilucent clouds and polar auroras. P.I. Klimuk and V.I. Sevast'yanov succeeded in photographing and spectrographing noctilucent clouds and polar auroras from space. During the joint flight of the "Soyuz-Apollo" program A.A. Leonov and V.N. Kubasov carried out two interesting experiments from the "Soyuz-19" spaceship--"A Manmade Solar Eclipse" and "Photographing Sunrise."

From the "Salyut-5" orbital station first-expedition cosmonauts B.V. Volynov and V.M. Zholobov in July-August 1976 and second-expedition cosmonauts V.V. Gorbatko and Yu.N. Glazkov in February 1977 continued photographing, spectrographing and making visual observations of the earth and atmospheric formations in the interests of science and the national economy. An MKF-6 multizonal camera, which was developed by specialists of the GDR and USSR and manufactured at the national enterprise Carl Zeiss Jena, was installed on "Soyuz-22." Using this camera, cosmonauts V.F. Bykovskiy and V.V. Aksenov photographed simultaneously a number of regions of the territory of the USSR and GDR in four sections of the visible region of the spectrum and two sections of the infrared region.

A great number of visual observations and optical instrument studies of the earth's surface and atmosphere were made by G.M. Grechko and Yu.V. Romanenko, cosmonauts of the main crew of the first expedition of the "Salyut-6" orbital station. They contained studies of polar auroras, noctilucent clouds and atmospheric optical phenomena near the earth's visible horizon and multispectral photographing of the earth's oceans and land masses using the MKF-6M equipment.

Presented in the second chapter of this book are the main results of research on the visual system under conditions of space flight, which is necessary for the purpose of assessing the reliability of visual observations in space. Presented briefly is a procedure for studying the key functions of a cosmonaut's vision in flight. Preliminary results are given for an investigation of the dynamics of the change in functions of vision in space flight. The results of experimental research make it possible to draw the tentative conclusion that changes in the key functions of vision under the conditions of space flight are relatively small and that the vision of cosmonauts in flight is just as reliable as on the earth. This makes it possible to make extensive use of sight for making scientific investigations and for guiding a spaceship.

The third chapter is devoted to distinctive features of visual observations under conditions of space flight. In order to estimate the capabilities and analyze the results of visual observations, frequency-contrast characteristics of radiation sources, the intervening medium and the visual system are employed. The conditions are discussed for observing faintly glowing sources against a radiating background. In the twilight zone and on the day side of the earth a great influence on the ability to observe faintly glowing sources (stars, planets, zodiacal light, polar auroras and the like) is exerted by the background radiation of illuminators. In this connection estimates are made of the visible radiation of the sun and of the earth's atmosphere and surface scattered by illuminators. Several results from visual observations of the earth's cloud cover, water area and dry land are given.

Observations from space have added much that is new to the total picture of the study of the earth's atmosphere. Important results have been obtained in observing the emissive radiation of the earth's upper atmosphere and nocturnal and twilight horizon. An attempt is made in the fourth chapter to systematize, analyze and generalize the results of these observations and to give a description of the total pattern of the global distribution of the radiation of the earth's upper atmosphere. The radiation of the nocturnal atmosphere is discussed in detail. An analysis is made of the phenomenon called by A.A. Lenov "earth's azure belt." It is shown that is is possible to identify and study noctilucent clouds and aerosol layers in the mesopause on the night side of the earth. The reason is discussed for the twinkling of bright stars and planets before setting beneath earth's night horizon.

Of great interests are the results of investigations from space of the optical characteristics of the earth's twilight atmosphere. Discussed in detail are features of the formation of the radiation of the twilight horizon and a description of certain optical phenomena in the twilight zone is given. An interpretation of the "moustache" effect is given. The "moustache" effect was used to construct an overall picture of the global distribution of the radiation of the earth's atmosphere in the twilight zone with angles of descent of the sun beneath the horizon of greater than 10°. An analysis is made of observations of the solar corona during sunrise made by A.A. Leonov from the "Voskhod-2" spaceship, and in this connection the possibility of observing the solar corona and the emissive radiation of the earth's upper atmosphere near the twilight horizon is discussed.

In the same chapter the main results of rocket and satellite studies of the daytime radiation of the earth's upper atmosphere and of polar auroras are generalized. A discovery by Soviet scientists and cosmonauts based on the results of rocket sounding and studies from "Soyuz" manned spaceships is described. A hypothesis regarding a relationship between the vertical-radiation structure (horizontal inhomogeneity) of the daylight emissive radiation of the earth's upper atmosphere in the zone of the terminator and gravity waves is expounded. Aspects of investigations of the spatial structure of the daylight emissive radiation of the earth's upper atmosphere on the day side are discussed. Brief information is presented on the study of polar auroras. The results of observations of polar auroras from space are given.

The fifth chapter gives the results of visual and photographic investigations of sunrise, which have made it possible to conclude that the atmosphere of the earth and other planets, and of comets as well, can create a considerable mirror reflection with small glancing angles. In analyzing this phenomenon photographs obtained by American astronauts from the spaceships "Apollo-12" and "Skylab" were utilized. The conclusion regarding the ability of the earth's atmosphere to create a considerable mirror reflection with small glancing angles was utilized for interpreting certain atmospheric optical phenomena observed on the earth's surface. These include the mysterious fire of Mpara, the green flash, the hovering islands, etc. Using the example of recording the mirror reflection of the sun from the comet Kohoutek, the ability to utilize this phenomenon for the purpose of studying the refractive index and density of the atmospheres of planets and comets is demonstrated. The possibility of studying the mirror reflection of the sun from the atmosphere of Venus is discussed.

Optical observations in space are a very important part of the extensive program of research on the natural environment from space. Already much information on various properties of the earth's stmosphere and ocean and land masses has been obtained, previously unknown atmospheric optical phenomena have been detected, and new data have been recorded regarding the emission of stars, planets, nebulae and the interplanetary and interstellar medium. This information has been used extensively both for scientific purposes and for solving numerous national economic problems.

The history of the development of optical research in space serves as an example of the systematic study and mastery of outer space. It clearly reveals the meaning of Konstantin Eduardovich Tsiolkovskiy's words, "Man will not remain eternally on earth, but, in pursuit of light and space, will first penetrate beyond the limits of the atmosphere and then will conquer for himself all the space around the sun." Information-gathering and power optics have an exceptionally great role in this. The future of mankind is closely tied to the extensive development of space optics, and our descendants will not forget that the history of optical research in space began in our country.

Conclusion

Before the space era, we earthlings could have been compared with a person at the bottom of a deep well trying to imagine what is taking place beyond its limits. Actually, from the earth's surface, being the floor of a vast ocean of air, through the atmosphere's relatively narrow translucent "windows" it is not easy to imagine the entire picture of the many physical processes and phenomena taking place in near-earth space and in near and remote space. Since the start of the space era extensive possibilities have been opened up for optical studies of the natural environment from space, as well as for detailed studies of planets of the solar system from short distances and even from their surfaces.

During the space era extensive data from optical observations have been gathered, which has made it possible to refine substantially many notions regarding the earth's atmosphere and surface, the sun and planets of the solar system, stars, and stellar formations and associations. Simultaneously with the accumulation of observation data the programs, methods and equipment for optical studies from space have been improved. During this period several key trends in optical research from space have emerged. First among these to be mentioned are studies of time, spectrum-energy and polarization characteristics, as well as the recording or observations of spectrum-region images of the earth's cloud cover, ocean and land masses through the atmosphere's translucent "windows" for the visible and infrared regions of the spectrum. These studies, conducted by means of photographic, spectrophotometric, television and infrared photography equipment, are necessary for solving many scientific and national economic problems in geology, geography, meteorology, agriculture, forestry, water conservation and the fishing industry. For these studies it is necessary to make a thorough study of the transfer functions of the atmosphere, illuminators and protective windows of optical equipment through a combined ground, aircraft, aerostat and space experiment.

Of great importance in studying the earth's upper atmosphere are studies of the time and space distribution of the spectrum-energy and polarization characteristics of the radiation of the upper atmosphere and of its individual components (nocturnal, twilight and daylight emissive radiation, polar auroras and mesospheric clouds, stable auroral red arcs, etc.) Touching upon these investigations is the study of the space and time distribution of optically active components of the atmosphere (aerosol, water vapor, ozone, OH, etc.), as well as of atmospheric optical phenomena observed near the earth's visible horizon.

Of exceptionally great importance for studying planets of the solar system, especially for the detection of signs of life, are detailed optical studies with high spatial resolution from space apparatus located at relatively short distances from planets or on their surface.

Studies of the time, spectrum-energy and polarization characteristics of stars, stellar formations and associations, and the interstellar and interplanetary medium in the ultraviolet and infrared regions of the spectrum which are inaccessible for ground studies are the basis for further progress in astronomy and cosmogony.

The development of optical studies from space is closely associated with the development of new methods of making measurements and of measuring equipment and of methods of data processing and transmission. A decisive role is played here by ensuring the required measurement accuracy, as well as of the appropriate spectral, spatial and temporal resolution.

It can be said with complete confidence that optical studies from space, which are of great scientific and applied value, represent one of the most important trends in space research. The further development of these studies will indubitably produce a lot which is new, both for solving national economic problems and for studying the natural environment from space.

CONTENTS

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LIFE SCIENCES

BIOLOGICAL RESEARCH ON COSMOS BIOSATS

Moscow BIOLOGISCHESKIYE ISSLEDOVANIYA NA BIOSPUTNIKAKH KOSMOS in Russian 1979 signed to press 25 Mar 79 pp 4, 237-239

[Annotation, table of contents from book edited by I.I. Bryanov, A.I. Burnazyan, Ye.I. Vorob'yev, O.G. Gazenko, A.M. Genin, S.A. Gozulov, N.N. Gurovskiy, A.V. Yeremin, L.I. Kakurin, A.G. Kuznetsov, E.F. Panchenkova, N.M. Rudnyy, Izdatel'stvo Nauka, 1,000 copies, 239 pages]

[Text] Annotation. The book summarizes the results of the research on the latest Soviet biosatellites, including the results of experiments performed in accordance with the joint Soviet-American program on the "Cosmos-782" and "Cosmos-936" artificial earth satellites. The ability of earth organisms to exist under conditions of weightlessness and the potential replacement of natural gravity by artificial gravity as well as problems associated with the effects of ionizing radiation during space flights were studied. Considerable attention has been devoted to preparation and control of biosatellite flights, life-support systems, and data transmission and processing methods.

The book is intended for specialists in the field of space biology and medicine.

53 tables, 72 illustrations, 9 pages of bibliography.

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SPACE ENGINEERING

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STRUCTURE OF SPACE VEHICLE MEASURING SYSTEMS

Moscow STRUKTURA KOSMICHESKIKH IZMERITEL'NYKH SISTEM (Structure of Space Vehicle Measuring Systems) in Russian 1979 signed to press 23 March 79 pp 2-9, 224

[Annotation, foreword, introduction and table of contents from the book by S.D. Sil'vestrov and V.V. Vasil'yev, "Sovetksoye Radio," 224 pages]

[Text] Annotation. The vigorous development of space research has enhanced the role of systems for the navigational support of flights. This book examines the principles for synthesis of radioelectronic systems for measuring space vehicle flight parameters, the dynamic matching of components, compression of measurement data and quasioptimum methods for their processing. The book is intended for scientific workers and engineers engaged in designing radioelectronic complexes as well as for students in higher courses at technical schools.

Foreword. The vigorous development of the volume of space research has increased the role of navigational flight support, and the increasing requirements on the technical specifications of measuring systems have led to their considerable complexity. It was necessary to investigate the problems involved in optimization of measuring systems, excluding unjustified expenditures involved in the creation of nonoptimum systems. The approach to synthesizing measurement structures must be systemic, but the key direction in investigations determining the structure of the measuring system as a whole and its individual components is the proper use, processing and transmission of measurement data.

With this premise as a point of departure, in determining the structure of the measuring system the emphasis is not only on the requirements on the characteristics of the vector of state of the vehicle, but also on ensuring the functioning of this system. The solution of such problems involves multidimensional methods for analysis of the conditions of the measurement process. Accordingly, in the book emphasis is on methods for multidimensional linear and nonlinear filtering, smoothing and the prediction of vehicle motion. For economy in our exposition, vector and matrix directions are used in the book. However, in the analysis of quantitative expressions, for the purpose of clarity we have frequently given examples in which scalar representations are used.

The introduction, #1.2, 2.2, 3.1, 3.2, 3.3, 4.4, 6.3, 6.4 and Chapter 5 were written by S.D. Sil'vestrov. The remaining sections of Chapters 1-4 were written by V.V. Vasil'yev. Sections #1.1, 6.1, 6.2 were written by the authors together. The remaining materials in the book are based on the original investigations of the authors.

In the writing of Chapter 5 and #1.2 use was made of the works and consultation of A.V. Tsepelev, Chapter 6--Yu.A. Yerokhin. The authors express appreciation to Doctor of Technical Sciences B.V. Petrov, Candidate of Technical Sciences A.A. Yakovlev and V.O. Shakhov for a series of valuable comments and advice which were taken into account in preparing the manuscript for publication.

Introduction. Radioelectronic systems for measuring space vehicle flight parameters are large systems consisting of many components. The functional problems which these components solve, the features of their physical realization, the algorithms and the work program can differ substantially. But despite this it is always possible to formulate the general problem, some integral criteria of the quality of system operation as a whole. Therefore, the problems relating to the synthesis of a system for measuring flight parameters and its subsystems must be approached from the standpoint of systems engineering. The systems approach must be based on multidimensional synthesis principles which are determined primarily by the multidimensionality of the system quality criterion. A complex system must be optimized using many special criteria, such as accuracy, noise immunity, reliability, handling capacity, adaptivity, cost and operational efficiency. This list can be extended. Here we will only emphasize the need for synthesis of the system, to some degree taking this multidimensionality of the system quality criterion into account. The solution of this problem is complicated by the fact that the structure of the system is also inevitably becoming multidimensional. If one uses the concepts of multidimensional spaces, the system must be multidimensional in geometric and time space, in parameter space, in signal and noise space.

Proper allowance for these multidimensional aspects is a basic and fundamental means for the synthesis of an optimum system.

The structural multidimensionality of the system for measuring flight parameters is manifested, in particular, in the multiplicity of components.

The systems approach forces us to desist from a completely isolated analysis and synthesis of individual components and subsystems. The systems approach can be illustrated simply in the example of several successively joined components each of which exerts an influence on the resulting measurement accuracy. Assume, for example, that the first component is the basic measuring instrument providing evaluations of the measurable flight parameters and the subsequent links solve the boundary-value problem, that is, determine the initial conditions of motion.

In an isolated examination of the components it seems indisputable at first glance that with an increase in the accuracy of measuring flight parameters by the primary measurement device, there will also be an increase in the accuracy in determining the initial conditions of vehicle motion. Accordingly, taking into account the increasing requirements on the accuracy in determining the orbital parameters it is necessary in every way possible to increase the accuracy in determining the measurable parameters, etc. However, the systems approach to synthesis of the measuring system as a whole immediately reveals a logical and formal error in such reasoning which in a general formulation can be regarded as "going astray."

In addition, the following question must be posed: what is responsible for the increase in accuracy in determining the measurable parameters? If it is due to the influence exerted on statistical characteristics by interference (decrease in the intensity of the internal noise of the receiver, false readings due to external interference, etc.), an increase in the accuracy of the primary measurements improves the accuracy in determining the flight parameters as a whole. However, if this accuracy is increased due to a decrease in the redundancy of measurements, the resultant accuracy can deteriorate. This corresponds to one of the theorems in systems engineering: synthesis of an optimum system, consisting of successive components, using some particular quality criterion, must be accomplished using components which are nonoptimum with respect to this criterion. This regularity facilitates the synthesis of the system on the basis of a multidimensional optimality criterion since it makes it possible to satisfy different mutually contradictory criteria, such as accuracy and noise immunity, in different sections of the measuring system. The systems approach also makes possible an economical assurance of the complex's high quality despite a decreasing quantity of information. A modern measuring system has a limited energy and time resource. Although the problem of measuring flight parameters is important (without whose solution it is not always possible for the space vehicle to carry out its functional mission), nevertheless it is frequently not the principal problem.

The volume, complexity and quantity of fundamental information arriving from the space vehicle will undoubtedly increase. This means that the energy and time resources that can be expended on obtaining and transmitting trajectory information will decrease. However, the requirements on the quality of the trajectory information are becoming increasingly rigorous. With respect to the requirements on the accuracy of the measuring systems, they are equivalent to the requirement of a decrease in the errors in measuring the flight parameters by one or two orders of magnitude in comparison with existing systems. There is an extraordinary increase in the requirements on noise immunity, reliability and cost of the complexes.

Under these conditions the systems approach makes it possible to raise the question of the most complete use of the information arriving at the input of the measuring system. Analysis indicates that there are enormous losses of information because its processing is not optimum and there is no unifed evaluation of the capabilities of the system as a whole.

Sometimes this is objectively related to the impossibility of complete use of the information excess as a result of the low speed or inadequate memory of the computer, but very frequently to traditions and habits corresponding to other conditions and requirements. For example, the idea exists that the principal contribution to the accuracy in evaluating the parameters of a random process is from uncorrelated samples. If this idea, which for the most part is correct, is extended to any set of correlated and uncorrelated random values, it becomes incorrect. A knowledge of and allowance for correlations and other relationships can exert a decisive influence on improvement of measurement quality. Multidimensional values for the characteristics of random processes play a positive role.

They make it possible to reduce the dispersion of errors in primary filtering (determining the values of parameters to be measured) and to give such output representations of these evaluations as will best ensure the quality of the output effect of the system as a whole. In actuality, only these aspects make it possible to overcome or smooth to some degree the contradiction between such highly important characteristics of measuring systems as their accuracy and noise immunity. In general, a modern measuring system can be regarded as a complex multidimensional space-time filter. In the last analysis the task of the measuring system is to determine the orbital parameters meters with stipulated quality criteria and assurance of its normal functioning. This problem is solved by the processing of measurement information obtained by the measuring device in the course of a measurement session.

The best values for measurable parameters can be obtained with optimum processing of the entire mass of available information. If this processing is carried out in a real time scale, a multidimensional filter synthesized in the manner of Kalman filters is optimum. The theory of such filters has been developed applicable to a linear model of motion and the maximum accuracy criterion.

It is really necessary to solve the strictly nonlinear problem because the parameters of the state vector of the object are nonlinear functions of the measurable signal parameters. The motion of an object, taking into account the random perturbations acting on the object, is a random process described by a system of stochastic differential equations. This random process can be regarded with adequate basis as a Markov process.

Markov approximations make it possible to obtain realizable structures of an optimum multidimensional nonlinear filter. The structure of such a filter must ensure minimum distances in the normalized state space between the true and rated parameters of the state vector. This means that it must be described by the same differential equations as the dynamic state vector of the object.

In this book an attempt is made at synthesis of the optimum structure of such a nonlinear multidimensional filter not only with respect to the accuracy criterion, but also with respect to the noise immunity criterion. The essence of synthesis is that a set of systems, to which belongs the model of formation of the parameters to be ascertained, is determined. The set of filtering systems is also related to it. A subset in which a system satisfying a given test of effectiveness of the values is determined in this set.

A feature of such a method for the synthesis of a nonlinear filter is that for a quantitative value of the filter parameters it is necessary to know the law of distribution of filtering errors. In analytical form it is exceedingly difficult to solve the problem of determining the law of distribution of filtering errors. Accordingly, a final solution to the problem is possible using numerical methods for integration of the differential equations of the moments of distribution of filtering errors.

Since the nonlinear dependence of the signal parameters on the parameters to be measured is unambiguously determined in a narrow region, the stability of the nonlinear filter is determined by the probability that the values will not fall outside this region. In a general case the maximizing of this probability leads to a bias of the values, which contradicts the accuracy requirements on the values.

This requires the use of a second component, which on the basis of statistical methods, in particular, the dynamic matching method, transforms the filter values into unbiased values.

The multi-component nature of the structure and distribution of measuring devices at a sufficiently great distance from the processing facilities dictate the use of different methods for the preliminary processing and compression of data. For this reason much attention has been devoted to the problems involved in the dynamic matching of the components, quasioptimum methods for the processing and compression of data.

The problems involved in the analysis and synthesis of optimum measuring systems have found their reflection and development in many studies of Soviet and foreign scientists.

A major contribution to the theory of construction and optimization of trajectory measuring systems has been made by V.Ye. Dulevich, S.I. Bychkov, V.S. Shebshayevich, V.N. Tipugin, Ya. D. Shirman, A.A. Korostelov, P.A. Agadzhanov, P.V. Olyanyuk, and others.

These studies, in particular, reflect the problems involved in evaluating the capabilities of systems, detecting optimum structural relationships and the systems approach to measuring complexes. In such an approach the "mathematization" of the measurement process acquires special significance; this is expressed in the fact that computers are entering into the makeup of measuring systems as their organic and fundamental components.

Only the broad introduction of mathematical structures into the makeup of measuring systems will make possible the most complete and optimum use of the reserves for improving the fundamental characteristics of these systems, hidden in the enormous quantity of received information. "Mathematization" will make it possible to combine the tasks of operational control, technological support and optimum processing of information. It is opening up ways to overcome the contradictions between ensuring a pre-defined systems quality with respect to various efficiency criteria, and in particular, the contradiction between the conservative directions in design, that require stable and consistent solutions, and the problems involved in modernization and adaptation caused by changes in the measurement objectives.

In this book an attempt has been made to develop this highly important direction in the synthesis of measuring systems.

The book does not touch on many problems pertaining to synthesis of measuring systems related, we assume, to the construction of antenna systems, SHF units, propagation conditions, etc. because its principal thrust is validation of the measurement system structure from the main information aspects.

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MONOGRAPH ON SPACE VEHICLE SOLAR CELLS

Moscow ITOGI NAUKI I TEKHNIKI: ISSLEDOVANIYE KOSMICHESKOGO PROSTRANSTVA, Vol 13, SOLNECHNYYE BATEREI V USLOVIYAKH VOZDEYSTVIYA KOSMICHESKOY RADIATSII (Results of Science and Technology: Space Research, Vol 13, Solar Cells Under Conditions of Exposure to Cosmic Radiation) in Russian 1979 signed to press 18 Jun 79 pp 4, 127

[Annotation and table of contents of monograph by L. B. Kreynin and G. M. Grigor'yeva, VINITI, 128 pages]

[Text] Annotation. In addition to concise information on cosmic corpuscular radiation and general concepts on the physical principles of solar cells, this monograph discusses: the mechanisms and efficiency of damaged photoconverters depending on the type of energy of cosmic radiation, influence of orbital parameters on the rate of degradation of solar cells; protection of solar cells on space vehicles against radiation; methods for increasing the resistance of solar cells to the influence of cosmic radiation. The book was prepared on the basis of materials in the Soviet and foreign press. An extensive bibliography is included.

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SPACE APPLICATIONS

ANALYZING SPACE PHOTOS FOR TECTONIC-MAGMATIC AND METALLOGENIC STUDIES

Moscow ANALIZ KOSMICHESKIKH SNIMKOV PRI TEKTONO-MAGMATICHESKIKH I METALLOGENICHESKIKH ISSLEDOVANIYAKH in Russian 1979 signed to press 2 Mar 79 pp 5-18

[Book edited by I.N. Tomson, Nauka, 1400 copies]

[Excerpt] Chapter I. Some New Trends in Tectonic-Magmatic and Metallogenic Forecasting Studies

Modern progress in geophysics, oceanology and space research, which has made it possible to consider the earth as a unified system and to obtain new information about its abyssal structure, has had a significant influence on metallogenic theory. At the same time the interests of the national economy have come more and more persistently to demand a transition from regional metallogenic structures accompanied by the isolation of extended specialized zones and belts to local prediction of ore bodies.

The new trends have expanded the class of problems involved in metallogenic analysis. Thus, along with investigating metallogenesis connected with the phases of geosyncline development of regions, the concepts of the metallogenic role of the processes of tectonic-magmatic activation occuring under the influence of deep, subcrustal conversions have appeared (Karpova, 1968; Shcheglov, 1968; Favorskaya, Tomson, et al., 1969). When investigating the tectonic control of magmatism and mineralization, the primary accent was transferred from the phases of development of the geosynclines to the differential movements of blocks and the systems of dislocations bordering them [98, 102].

It was demonstrated that during the periods of activation, the leaders of melts and solutions of different depth are definitive types of disturbances. At specific sites the relation of the evolutionary magmatic series to the differential movements of the blocks has been established, and the ideas of parallel-operating magmatic centers have been advanced. Summing up, two types of block structures and fractures have been isolated, distinguished by depth of occurrence--"through"--on the one hand, and "earth's crustal structure" on the other [102].

The "through" type structures encompass various segments of the geosynclines and platforms, and they have deeper roots. Their boundaries appear, as a rule, in the form of systems of geological and geophysical anomalies. Although the structures of the earth's crust are among the shallower structures, it is impossible to exclude the possibility of the well-known relation to the abyssal zones of the earth.

When investigating the periods of increased tectonic and magmatic activity, two basic types of this activity were isolated. The abyssal activity of the first type occurs under the conditions of predominant tension, and the activity of the second type--the "orogenic" type--in a situation of predominant compression. Among the tectonic formations connected with activation of the latter, the center structures deserve special attention.

According to the concepts previously advanced by us [111], the center structures are closely connected with the palingenic crustal centers, and they are found in direct dependence on their dimensions and the peculiarities of their development. The proposition has been stated that the participation of subcrustal processes is not excluded in the formation of center structures, for the palingenic centers themselves occur, probably under the effect of abyssal thermal fluxes and fluxes of endogenic material. The following were advanced as the basic signs of center structures.

1. The center structures are superposed on plicative dislocations.

2. They are characterized by a system of internal dislocations among which the primary role is played by radial-concentric dislocations.

3. The areas of magmatism characterized by obvious predominance of rock similar to them with respect to age and genetically related to each other are spatially connected with the center structures.

4. They are characterized by individual anomalies of the geophysical fields. The gravitational minima have special significance among the latter.

5. Ore zones, accumulations and fields are often spatially connected with the center structures of various sizes. The internal dislocations of these structures control the distribution of the individual deposits.

The idea has also been advanced of primary and secondary center structures. The first type includes the corresponding formations reaching 400 to 1500 km^2 in area. It was proposed that the composition of the rock of which they are made indicates unity of the initial center. The secondary center structures are characterized by areas from 10 to a few hundred square kilometers. The magmatic areas accompanying them are derivatives of the intermediate centers, and the composition of the rock reflects primarily the various types of processes of differentiation and contamination occurring in the intermediate chambers and at the place of development of intrusions.

The interference of abyssal pulses leads to synchronous appearance of magmatic series arising from various sources. Therefore along with the two main types of magmatism determined by the condition of development of the through megablocks, there is a third type, the occurrence of which obviously arises from the deepest transitions. This type of magmatism appears within the special type structures which we previously isolated under the name of "ore concentrating structures."

In recent years the concept of ore-concentrating structures has been developed in detail by collectives led by I.N. Tomson and M.A. Favorskaya, and it has become the basis for new metallogenic construction [109]. The studies of these collectives made in Eastern Transbaykal, in Primor'ye, on Kamchatka and in the territory of the Armenian SSR and also the analysis of a large amount of published material on foreign territories have led to the conclusion of the existence of linear zones of penetration of deep occurrence.

It has been established that they intersect not only the boundaries of the structures of the earth's crust, but also the continental boundaries with the oceans, that is, they are of a "through" nature. In the overwhelming majority of cases the strike of these zones is either latitudinal or meridional. Within the boundaries of individual large regions one such system always has greater significance for the endogenic processes than the second one associated with it and in such cases appearing as an auxiliary system. Many of the systems can be considered as global with respect to extent, and they constitute the deep skeleton of our planet. With respect to width first-order structures are distinguished among them, which are systems of large blocks reaching 500 km across. For example, the ore-concentrating system of blocks cutting across the United States and Canada between 47° and 51° north latitude is this type of structure. Such very large belts usually include two or three second-order systems coinciding with them with respect to strike. These second-order systems have a block width of 100-200 km. They, in turn contain ore-concentrating systems of faults 20-40 km wide [95].

It has been established that the ore-concentrating systems of dislocations are long-lived, and their strike corresponds to the structural plan of the most ancient precambrian formations of the basement of the given region. Occurring in the precambrian, they were revived later several times during periods of tectonic-magmatic activity.

The study of the peculiarities of the endogenic processes connected with them has led to the conclusion that they control specific magmatism. Thus, V.A. Baskina [5] demonstrated in the example of the territories of the Far East, South Africa, Canada and the United States that the ore-concentrating systems of dislocations were already in the early Archean represented by latitudinal and meridional systems of volcanic belts separating the areas of active granite formation. The nature of the magmatism of the ore-concentrating structures determines their type over the entire extent of the history of their development.

According to V.A. Baskina the characteristic features of the formations occurring here include the combination of series and contrast differentiated (stratiform) basaltoid and andesitic series, variety of petrochemical types of basalts and the presence of ultrabasic lavas. All of this indicates the multiple alternation of the compression-tension conditions and significant inflow of heat. The magmatism of increased alkalinity appears against a background of predominantly tholeiitic series at the intersection nodes of differently directed systems of disturbance of deep occurrence. All of the known stratiform intrusives are localized in the largest ore-concentrating belts.

Everything that has been stated permits consideration of the ore-concentrating structures as zones of special abyssal permeability, and the magmatic rock associated with them can be isolated as a basic, third group of magmatic formations along with the above-noted groups of formations characterizing the magmatism megablocks as a function of the tectonic conditions of compression and tension.

As a most important metallogenic conclusion it is possible to consider that the ore-concentrating systems of dislocations intersecting the metallogenic zones with different ore specialization determine (at the locations of such intersections) the occurrence of large ore bodies of the corresponding profile. Accordingly, the problem has been stated for the first time that large ore accumulations of industrial significance are characterized by a specific tectonic position distinguished from the position of small ore bodies. This has made it possible to isolate the described systems of deep dislocations as "ore-concentrating," and it has determined their important role in the development of methods of predicting deposits.

The discovery of the orthogonal system of abyssal zones of permeability has permitted a new approach to the problems of global metallogeny. As is known, some modern researchers, both in our country and abroad, are at the present time trying to use the latest hypotheses of global tectonics and, above all, the so-called plate tectonics, for metallogenic analysis.

The analysis of the available data has demonstrated that in many cases the strike of the ore-concentrating systems of faults is perpendicular to the "plate" boundaries and coincides with the direction of their proposed movement. Thus, for example, some of the long-lived through dislocations of North America continue into the adjacent parts of the Pacific Ocean floor in the form of well-known latitudinal dislocations (the Mendocino, Murray and other fracture zones) [100].

In addition, the nature of the endogenic processes connected with ore-concentrating systems of dislocations indicates more abyssal occurrence of them by comparison with the dislocations which constitute the boundaries of the proposed plates. This is indicated at least by the above-presented data on the magmatism of the ore-concentrating systems of dislocations [96].

The enumerated peculiarities of the ore-concentrating structures determine the nature of their appearance on the earth's surface. The general methods of analyzing hidden abyssal structures were developed by N.S. Shatskiy [114], and they were used by Ye.A. Radkevich, I.N. Tomson and N.V. Gorlov to discover hidden dislocations of the basement during metallogenic forecasting studies. A special study of the geological anomalies for the territory of Primor'ye was made by A.M. Kurchavov [97], who developed the successive procedures for discovery and cartographic representation of them.

It was also established that the "through" systems of dislocations of deep occurrence are clearly fixed by the peculiarities of the modern relief of the earth's surface. This is explained by the fact that the majority of large dislocations belong to the long-lived and multiply reactivated dislocations over the history of their development. Accordingly, I.K. Volchanskaya, N.T. Kochneva and Ye.N. Sapozhnikova [56] developed the morphostructural method of analyzing the relief permitting establishment with great completeness of the nature of the fracture tectonics of the investigated regions. Not only is the presence of the majority of dislocations reflected on the existing geological maps confirmed here, but the great extent of them and their morphological differences from those known before are revealed. An especially important advantage of the method is the possibility of detecting hidden systems of dislocations often escaping attention during geological surveys. Among the tectonic nodes occurring at the point of intersection of such systems by faults of other categories, prospective ones are discovered with respect to endogenic mineralization by comparing with the standard morphostructural position of the known ore bodies.

The ore-concentrating structures and accumulations of increased tectonic permeability have also been established by geophysical data and, above all, by the gravimetric and magnetometric data.

The study of the ore-concentrating systems of dislocations, the nodes of their intersections with other faults, just as the study of the specific structures of orogenic activation (including center structures) provided the basis for developing new methods of local prediction of ore zones, accumulations and fields. In particular, it was established that the structures of orogenic activation (arched uplifts, various types of superimposed basins) are found in complex relation to the ore-concentrating systems of dislocations. In some cases the young superimposed basins occur within the boundaries of these systems, running in accordance with them. The faults bounding such basins often turn out to be ore-concentrating . The arched uplifts, in the majority of cases, are located in spaces separating the ore-concentrating systems of dislocations. The joint of ring fractures surrounding the arches, with linear dislocations belonging to the ore-concentrating system appears to be the most interesting in metallogenic respects. The local forecasting in an area of ore-concentrating structures is based on studying their intersection nodes with the systems of dislocations on the orthogonal level complementing them and the large diagonal fractures. The above-noted "center structures" are connected with such nodes in individual cases. The study of their internal structure (the position of the ring and radial fractures, differential movements of individual sectors and so on) is an important link in the chain of successive operations for local forecasting of ore deposits.

The further development of metallogenic studies in the described area provides for dividing the continental and, later on, possibly the ocean territories into districts by isolating the ore-concentrating lineaments and nodes of their intersection with the fractures of other directions both cross-cutting the predominant plan of the region and in accord with it, and also the structures of orogenic activation. This type of division into districts can be accomplished with great effectiveness if in addition to geological studies, the deciphering of the materials from space photographs is used.

In the time that geologists have had space and high-altitude photographs at their disposal, the new, broad information obtained from them has quickly penetrated into all areas of geological study. The deciphering of remote photographs has revealed still newer possibilities for geological mapping than was obtained by morphostructural analysis of the relief. By decoding such photographs, many of the geological boundaries have been more precisely defined, and dislocation zones previously known in the form of individual fragments and so on have been isolated in sections inaccessible to direct observation. Along with the information allowing the results of ordinary geological studies to be checked and more precisely defined, certain information of a more special nature has been obtained. Thus, on the space photo-traphs abyssal dislocation zones which appeared on the earth's surface in veiled form have been to one degree or another clearly established.

As was mentioned above, along with morphostructural and geophysical methods, the special analysis of geological anomalies is used when studying them, among which an important role is played by such attributes as bends or "splitting" of the large fractures, virgation of the folds, oriented in accordance with the strike of the described systems of fields of effusives or the long axes of the intrusive massifs, similar orientation of superimposed basins, the appearance of magmatic formations of increased basicity or alkalinity, and so on. All of these signs summed up on special maps of geological anomalies trace the hidden systems of dislocations, and along with the corresponding peculiarities of the relief, they create a defined effect on the space photographs clearly distinguishable by visual observation.

Here we encounter one of the important properties of remote materials, the analysis of which permits the assignment of the nature of directly observable, reliable facts to complex geological structures. Attention is attracted by the fact that the nature of the information received from space and high-altitude photographs is especially favorable for checking out and substantiating the metallogenic concept based on the representation of the primate of hidden dislocation zones in the process of the distribution of large accumulations of endogenic mineralization. In this case the use of remote materials to a significant degree eliminates the difficulties which arise on the path of geological investigation of abyssal structures appearing on the surface in veiled form. In contrast to this, the traditional structural-metallogenic zones determining the nature of ore specialization were in the majority isolated on the basis of tectonic signs most clearly manifested on the surface. As a result, they attracted the attention of the metallogenists long before the new data advanced the systems of hidden abyssal dislocations to the forefront in this region.

The use of space photographs also turned out to be extraordinarily favorable when studying the nodes of increased tectonic permeability and ring, including center, structures. It was established that the ring structures play an important role in the structure of many territories and that structures of different sizes can be discovered on photographs of different scale in accordance with the generalization effect. Their study has helped to obtain new information about the makeup of the center structures.

In spite of the fact that the abyssal systems of dislocations were also established previously in some cases by geological and morphostructural methods, the use of space and high-altitude photographs not only has confirmed the conclusions obtained, but it has opened up theoretically new possibilities. It turned out that the development of new specialized procedures for studying the photographs has permitted the establishment of latent laws of the internal structure of territories which are theoretically new and from all of the available data most compatible with the geophysical, gravitational and magnetic anomalies. The study of macrojointing is among such procedures. As the analysis performed for the territory of Primor'ye by Ye.V. Akimova and V.V. Yarmolyuk has shown, the method permits detection of previously unknown structural directions and reveals new characteristics of the previously established elements of the geological structure of the region. Thus, during the analysis of macrojointing by high-altitude photographs in the Kavalerovo-Dal'negoskaya ore-concentrating zone, its discontinuous nature with alternation of sections sharply differing with respect to density of distribution of the jointing in the latitudinal and meridional direction was established for the first time [118]. Although the development of this method has still taken only the first steps, it is possible to state with certainty that its application is opening up a new age in the study of the peculiarities of the appearance of abyssal tectonics on the earth's surface. The discovery of zones of accumulation of macrojointing in the territory of Primor'ye has demonstrated all the variety of interrelations between the clusters of differently directed joints.

In cases where the directly observed joint cluster zones experience virgation, as if encountering invisible obstacles and the "disturbance nodes" arising in this case, in turn, are set up within the boundaries of a single linear anomaly, it is possible to propose that we are dealing with abyssal systems of dislocations in different form reaching the earth's surface. In these cases the entire complex picture of the jointing is gradually deciphered as a system of interconnected structural elements occurring at different depth. The study of these laws will gradually permit an approach to the solution of interesting and important problems of the effect of the systems mentioned on the processes of magma formation and ore formation and the distribution of the magmatic complexes and ore deposits.

At this time the method of deciphering macrojoints is still very tedious. However, in the near future it is possible to expect significant simplification of it by using special photographic techniques and computers which will expand its possibilities still more.

Summing up everything that has been discussed in this chapter, let us note that the development of methods of studying and deciphering remote materials has been approached determinedly and it has been directed both toward further proving previously established principles and further developing and more precisely defining the concept discussed above in its tectonic-magmatic and metallogenic aspects.

Chapter II. Methods of Deciphering Space Photographs for Tectonic-Magmatic and Metallogenic Prediction Studies

1. Videoinformation Received From Space

At the present time the problems of using materials received from space for geological studies is the subject of a significant amount of literature published in the USSR and abroad. In the USSR the largest studies in the field of using space photographs have been made since the beginning of the 1960's by various subdivisions of the "Aerogeologiya" All-Union Scientific Production Association, and since the beginning of the 1970's, by various institutes of the USSR Academy of Sciences and many scientific, production and training organizations. The results of these studies have been discussed in a large number of publications, among which it is necessary to note the generalizing work of the collective of the Aerial Methods Laboratory of the USSR Ministry of Geology published in 1975 KOSMICHESKAYA FOTOS'YEMKA I GEOLOGICHESKIYE ISSLEDOVANIYA [Space Photographic Surveys and Geological Studies] and also TRUDY KOMISSII PO ISSLEDOVANIYU PRIRODNOY SREDY KOSMICHESKIMI SREDSTVAMI [Works of the Commission on the Study of the Natural Environment from Space] edited by L.A. Vedeshin, V.G. Trifonov, P.V. Florenskiy (1973-1976).

In this book we shall limit ourselves to brief information about some of the aspects of space videoinformation which have direct bearing on the tectonic-magmatic and metallogenic studies developed at the Institute of Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry of the USSR Academy of Sciences since the middle of the 1960's.

The images of the earth's surface used at the present time for geological purposes are obtained by several methods with the aid of equipment installed on various carriers (aircraft, rockers, artificial earth satellites, manned spacecraft, permanent orbital stations, automatic interplanetary stations, and so on). The procedures for obtaining information in the first approximation can be divided into photographic and nonphotographic. The photographic information is distinguished by high resolution by comparison with nonphotographic, but the latter can be obtained more operatively, and in greater quantity, and therefore it permits selection of representations of one section or another under favorable conditions (a pre-determined time of day, time of year, clear weather, and so on).

A common feature for all the images is the fact that the geological formations on them are reflected in greatly diminished, generalized form. The degree of generalization of the image depends on the territory encompassed or the field of view of the photographs and their resolution.

Inasmuch as the resolution of photographic and nonphotographic systems is different on the same scales, it is meaningful to consider them separately, for the degree of generalization of images of the same scale obtained by different methods will be different. The degree of generalization determines the geological informativeness of these materials. For quantitative determination of the degree of generalization, the concept of generalization level is proposed which can be determined by dividing the altitude of the photograph by the focal length of the camera objective [85]. In the first approximation it is sufficient to know the order of magnitude of this.

Photographs. The first photographic images of the earth's surface from space were obtained from experimental rockets using automatic cameras installed on board them.

The first experiments performed in the United States in which photographs were taken from altitudes of 40 to 370 km both in the visible and in the infrared range of the spectrum made it possible to recognize cameras with from 60 to 80 mm film and a focal length of 65 to 80 mm as optimal; they were later installed on the Gemini and Apollo manned spacecraft. Various combinations of types of film and light filters made it possible to find the optimal photographing conditions. These were single photographs by means of which the conditions of taking the photographs from high altitudes were worked out. It was discovered that the basic factor interfering with photography is the earth's atmosphere, which transmits waves only of a defined length (optimal transition for waves of 3.6-4.1, 8.7-9.0, 10.3-12.0 microns.)

The atmosphere turns out to be opaque for the ultraviolet part of the spectrum; usually visible and infrared radiation is used in photography.

Various compact cameras with a focal length of 30-300 mm were installed on the Soviet manned spacecraft from the very beginning. The level of generalization of the images was 10^7, 10^6, $n \cdot 10^5$ from a flight altitude of 200-400 km. Still higher level of generalization (10^8) was achieved when photographing the entire visible disc of the earth from the "Zond-5" and "Zond-7" automatic interplanetary stations and the lunar expeditions of the Apollo manned spacecraft. The resolution in the terrain fluctuated from $n \cdot 10^m$ (level of generalization 10^5) to 6200 m for level of generalization 10^8. In the first approximation it is defined as the product of the denominator of the scale of the photographs times the distance between the centers of two adjacent white marks distinguishable on these photographs by eye, but it also depends on the contrast, that is, the brightness of the landscape elements.

The photographs were taken both in black and white and color and on spectrozonal film. The greatest resolution was obtained on the specially processed black and white films. Photography in narrow spectral intervals was started in 1969 (the so-called multispectral photography).

Nonphotographic Images. In addition to photographs obtained from film exposed in space and returned to the earth, in recent times a more and more important role has been played by videoimages received by television and scanner systems, transmitted to receiving stations on the ground when the space vehicles with the equipment show up in the radio visibility zone of the stations. Without discussing the technology for obtaining these images by optical and optomechanical television devices, let us only note that with time their resolution will become comparable to the photographic systems ($n \cdot 10$ m on the terrain). Recently multispectral systems have appeared which are capable of reproducing an image in several quite narrow spectral intervals. Let us present some examples of the images used by us which were received from the American natural resources satellite (ERTS-1) launched in July 1972 into a subpolar circular heliosynchronous orbit about 900-920 km high. The images are received in four spectral zones (0.5-0.6, 0.6-0.7, 0.7-0.8, 0.8-1.1 microns); the scanning angle is very small ($2\beta = 16.2°$), which increases the graphic and measuring properties of the pictures. The scanning is realized by rotating a mirror. The capture band width on the terrain is 184 km. At the receiving station the information is recorded on magnetic tape, and then it is reproduced on 55X55 mm photographic film, which gives a $1:3.2 \cdot 10^6$ scale.

The large number of lines permits multiple enlargements from these films; the resolution on the terrain according to NASA data is less than 100 meters. The picture is taken for each point of the earth at intervals of 18 days for ERTS-1 and 9 days for ERTS-2 (Landsat-2), at the same time of the morning (about 0900 local time). From several black and white images by synthesis in laboratories color pictures are obtained in false tones on which it is possible to isolate certain objects artificially. The possibility of electronic transformation of these images into cartographic projection greatly facilitates the gridding of the decoding results and insures reliability of their comparison with materials of the geological-geophysical studies.

2. Possibility of Geological Interpretation of Space Images of the Earth's Surface

As was noted in the preceding chapter, the use of space photographs has turned out to be especially prospective for metallogenic analysis based on the study of the role of different types of discontinuous linear dislocations and ring structures, including center structures. The first small-scale images of the earth's surface revealed an enormous increase in information about these structures.

The large field of view of the photographs has made it possible to detect or confirm the presence of largest, extended fractures determining the structural frame of one territory or another.

In view of the fact that the information obtained on deciphering these elements does not permit classification of them in one category of geological formations or another without additional studies, special terminology is used.

In foreign literature the most used terms are the following:

1) Lineament--lineament introduced by Hobbs (1904) for designation of the largest fractures expressed in the relief. At the present time various authors use it for designation of structures, the length of which exceeds 1.6 km [130,33];

2) Linear--linear elements of the relief [136, and so on] used in general for all linear forms of relief;

3) Fracture trace--traces of a fault of joints--for designation of structures less than 1.6 km long.

Four categories of lineaments are provisionally distinguished with respect to extent: from 1.6 to 8 km, from 8 to 80 km and from 80 to several hundreds, from hundreds to thousands of km. The latter are structures of transcontinental scale. In Soviet literature the term "lineament" has been applied to structures deciphered on space photographs in the paper by V.D. Skaryatin [83].

On the space photographs the lineaments are deciphered by special attributes: 1) extended boundaries separating regions with different tonality, configuration or texture of the image on the photographs; 2) a shift of fields of like or different decipherability; 3) rectilinear forms of relief or landscape; 4) independent linear geological formations (intrusions of basic and acid composition, dikes, and so on). Along with the geological structures all of the linear elements are deciphered on the space photographs, including traces of human activity (roads, canals, clearings, field boundaries, and so on). However, on comparison with geological materials the relation of the overwhelming majority of deciphered lineaments to fractures usually is well confirmed.

The isometric and ring structures are the second object of deciphering on the space photograph with respect to increase in new geological information. Their deciphering began somewhat later than the lineaments, and as a result the volume of accumulated information about them is appreciably less. In addition, it must be noted that the problem of the origin of the ring structures has attracted the fixed attention of geologists long before their appearance on the space photographs, and it especially increased after the possibility arose for direct deciphering by remote images.

Among the Soviet works where magmatic complexes connected with ring structures of different scales from "center" to the largest with transverse dimensions of a few thousand km have been specially investigated in the last decade, it is possible to note the monographs [102, 80].

The deciphering of remote materials has demonstrated that the ring structures enjoy broad development in territories with different geological structure and that some of them go beyond the limits of large regions with respect to their dimensions [87, 84]. Considering the problem of the genesis of such formations, A.V. Dolivo-Dobrovol'skiy and S.I. Strel'nikov [42] divide them into three types: 1) the earliest nuclei of consolidation of the earth's crust of more or less isometric outlines, corresponding to the epicenters of the fusion of the granite layer; 2) structures of the granite formation regions connected with the middle stage of geosynclinal development and occurring along with preservation of the above-noted ancient structures; 3) the structures of volcanic-tectonic genesis occurring in the late stage of geosynclinal development and in the subsequent stage of platform development.

However, it must be noted that modern ideas about the phenomena of tectonic-magmatic activity force us to assume closer heredity of the enumerated genetic types of ring structures experiencing revival during the process of the above-mentioned pulses of increased endogenic activity. The mechanism of formation of the ring structures differs. N.T. Kochneva and I.N. Tomson [61] note that such structures occur under the effect of various abyssal processes, including the dynamic effect of magmatic centers just as under the effect of explosive and seismic pulses and the impacts of cosmic bodies, and even as a result of exogenic preparation of the relief.

Dolivo-Dobrovol'skiy and Strel'nikova gave a great deal of attention also to the interrelation of ring formations with linear dislocations and with subsequent processes of fold formation. This problem is discussed also in an article by N.A. Gusev [31], where on investigation of the ring volcanic-tectonic structures of Kamchatka the author notes their close relation to the nodes of intersection of the most significant systems of dislocations with a break in continuity.

This relation is supported at the present time by quite broad factual material, and it can essentially be considered generally accepted. N.T. Kochneva and I.N. Tomson [61] note that usually the complexly constructed ring structures which are the most prospective with respect to the shows of ore type minerals usually are drawn to such intersection zones. In the territory of the United States in the Basin Region of Nevada and the ridges, L. Rowen and P. Wetlaufer [77], considering the circular forms of relief as volcanic centers, state the opinion that the polymetal mineralization is connected to a higher degree with the intersection nodes of the lineaments than with the ring structures. Nevertheless, these authors note that in the case where mineralization is associated with the volcanic centers tracing the linear dislocations, its relation to the ring structures is probable although not finally proved.

The problem of the metallogenic role of the ring formation is closely connected with the concepts of center structures noted in the introduction to the book [111].

During deciphering on the space photographs, these structures are detected either by their circular outlines or by the presence of positive or negative forms of relief. Their internal structure can either be concentric or radial-block. In the large structures more complicated patterns of internal dismemberment are encountered.

In addition to the dislocations with a break in continuity expressed on the space photographs in the form of lineaments and ring structures, in a number of cases a folded structure is well decoded. The basic condition of this deciphering is the presence of the so-called photomarking beds which appear in the case of interstratification in the section of thick series of rock of different density (the limestones of the Asmara suite in the Zheros Mountains, the limestones of the lower and upper Cretaceous in Dagestan, the quarzites of the Bami suite in Morocco, and so on). In the case where disharmony is clearly recognized in the nature of the dislocation of the various series, the structural mismatches are deciphered.

The deciphering of the peculiarities of the behavior of the plicative structures (virgation of the folds, the presence of pinches, and so on) is an important criterion when discovering the transverse and through systems of dislocations playing an important metallogenic role.

3. Geological Informativeness of Space Photographs of Different Levels of Generalization

Both for aerial photographs and for space images, the deciphering is of a landscape nature. Various geological structures are reflected in one way or another in various components of the landscape.

On the space photographs, the complex nature of the deciphering of certain elements of geological structure with respect to entire series of landscape components is manifested to a higher degree than on the aerial photographs. The greater the field of view of the space photograph, the more varied the natural territorial complexes reflected on one image and the lower the probability of random coincidence in their interpretation.

At very high generalization levels (10^8) where the entire earth is immediately visible and entire continents can be seen in the spaces that are free of clouds, we can isolate a set of various landscapes. The possibility of geological deciphering under such generalization conditions was first demonstrated by us in the example of analysis of a stereopair consisting of the initial and final photographs of a session of photographing the earth from the "Zond-5" automatic interplanetary station [84]. Among the well-known largest tectonic structures of North Africa, the previously unknown transcontinental lineaments were distinguished which are zones of splitting of the earth's crust extending several thousands of kilometers (Bakhador-Bakhariya, Levriye-Zorug, Ugarta-Dafur, and so on). Later analogous structures were distinguished in the territory of Arabia, Anatolia, the Near East, and Central Asia by color photographs from the "Zond-7" automatic interplanetary station [85,116] and photographs from the "Apollo" manned spacecraft during their lunar expeditions. Lineaments similar with respect to extent and large ring formations are also deciphered on mosaic reduced photographs compiled from many cloudless photographs from ERTS-1.

The lower levels of generalization (10^7) are achieved on images obtained from medium orbits (600-1000 km) of artificial earth satellites (Meteor, ESSA, and so on).

Unfortunately, they are difficult to compare with the preceding ones inasmuch as the technology for obtaining them differs basically from the photographic procedure. The band encompassing the terrain on such space photographs is reckoned in thousands of kilometers. Several types of landscapes can be reflected in them simultaneously.

Individual components of the landscapes are combined and the photographic tone of the picture is formed. From the geological structures individual parts of transcontinental faults, the most lengthy of the regional faults and the largest plicative structures of the meganticlinorium type are decoded on them. The possibilities of deciphering lithologic-stratigraphic complexes are extremelv limited here--only the basic types of Quaternary deposits are distinguished; in a number of cases sedimentary formations can be separated from the young dark colored igneous rock. Large ring formations are distinguished.

If we are talking about still more detailed space photographs (generalization level = 10^6), then here we can quite certainly decipher the plicative structure in the presence of photomarking horizons, determine the relation of the plicative dislocations and the dislocations with a break in continuity, the individual large folds between each other, and decode the individual sections of large faults and a quite large spectrum of small ones. On such space photographs it is possible quite clearly, although not very exactly, to isolate the basic lithologic-stratigraphic complexes, and to determine the basic types of Quaternary deposits certainly. The most varied ring formations with respect to size and type are deciphered.

At this generalization level most frequently the configuration of the images analyzed which is formed as a result of the combination of various landscape components, some of which have differentiated and others integrated representation on the photograph.

At still lower generalization levels (10^5, 10^4) we go into the realm of the aerial photograph, which we shall not discuss in this paper.

The physical meaning of the effect of generalization has not been fully explained as yet. Structures of different depths of occurrence are reflected on the photographs of different generalization level, and, as our studies have demonstrated, certain types of hidden "through" fractures are detected only at defined generalization levels, usually the highest. This is connected with the fact that the "through" structures, including ore-concentrated structures, have significant width (several tens of kilometers), and on more detailed photographs with small field of view and good resolution in the terrains such structures become "blurred" and a single structural element is not perceived.

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PAPERS ON SPACE PHOTOGRAPHY AND THEMATIC MAPPING

Moscow KOSMICHESKAYA S'YEMKA I TEMATICHESKOYE KARTOGRAFIROVANIYE (Space Photography and Thematic Mapping) in Russian 1979, signed to press 8 May 79 pp 2, 231-232

[Annotation and table of contents from the collection of articles edited by Doctor of Geographical Sciences N.V. Bashenina and Candidate of Technical Sciences Yu.M. Chesnokov, Izdatel'stvo Moskovskogo Universiteta, 232 pages]

[Text] Annotation. This collection of articles includes papers on the methods for using space information in the compilation of different types of thematic maps: landscape, geomorphology, hydrology and economic geography, as well as in the study and mapping of the anthropogenic effect on nature. The collection is intended for a broad range of geographers, geologists and cartographers as well as for specialists working in the field of aerospace methods and applied cosmonautics.

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